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JAPAN'S SATELLITE DEVELOPMENT PROGRAM

Summary

Japan's applications satellite program, which only recently entered the operational phase, has become a flash point in bilateral relations. Reagan administration trade policymakers claim that Tokyo has shut the door on purchases of foreign spacecraft as part of an effort to help Japanese manufacturers bridge the technology gap with American aerospace companies. Japan has refused to buy U.S. satellites, but government officials flatly reject Washington's contention that the Japanese satellite program is commercially oriented. They also point out that the issue is not as straightforward as U.S. trade negotiators suggest since the leading American satellite builders have design authority on Japan's projects and are the principal subcontractors.

Japan's Satellite Program Comes Under Fire

Reagan administration trade policymakers have made Japanese industrial policy a moving target of attack, zeroing in on one product, then narrowing in on another. Recently, their focus has shifted from semiconductors and machine tools to satellites. This new target popped up last summer when Nippon Telegraph and Telephone Public Corp. (NTT) representatives, on a buying mission here, expressed interest in acquiring software for communications satellites -- key links in the nationwide integrated communications/information network Japan's domestic telecommunications monopoly plans to construct by the end of this century.

U.S. aerospace companies, the world leaders in satellite technology and the dominant suppliers of communications satellites, parried these feelers, asking why NTT did not buy the satellites themselves. The response -- that Japan's space development program precludes the purchase of foreign satellites -- opened a new front in the Reagan administration's campaign against the trade-distortive effects of Tokyo's industrial policy. Secretary of Commerce Malcolm Baldrige unsuccessfully pressed former International Trade and Industry Minister Sosuke Uno last September for changes in Japan's satellite purchasing practices. United States Trade Representative William E. Brock raised the issue with Foreign Minister Shintaro Abe the following month, again to no avail. Subsequent discussions at the subcabinet level have also produced a standoff.

At first glance, Japan's exclusionary satellite purchasing regulations appear to be a government procurement issue. While often portrayed in this context, U.S. trade officials insist that the industrial policy framework is the appropriate one. By not permitting open international bidding for satellite contracts, it is argued, the Japanese government is shielding domestic manufacturers until they can develop and master the product and process technologies to compete in the world satellite market with American and European aerospace companies. Reagan administration trade negotiators add as well that their opposition to Japan's satellite development policy extends to all types of spacecraft -- scientific, meteorological, earth observation, geodetic, broadcast and communications, not just the latter, although they admit that communications satellites represent the high-growth segment of the market. The Japanese side, Washington says, recast the issue in terms of communications satellites alone.

The Japanese government does not deny that its space policy requires a domestic company to be the prime contractor on satellite projects. Spokesmen do, however, challenge Washington's version of the goals of the space program in Japan. The primary objective of Japanese space policy, they note, is to strengthen the nation's security in areas like communications, weather forecasting and remote sensing. Other basic goals include obtaining economic and scientific benefits through the exploitation of space and promoting international cooperative activities, especially with the National Aeronautics and Space Administration (NASA). These aims, it is emphasized, closely parallel those of the U.S. space program.

Commercial development is not a primary target, officials maintain. It is not even a secondary objective, they add, pointing to the big lead American companies have in satellite and launch vehicle technologies and the limited funds available in Japan for space development. In fact, at ¥113.4 billion (\$493 million at ¥230=\$1.00) in FY 1983, projected Japanese government funding of space activities is just a fraction of U.S. spending, which amounted to roughly \$10.6 billion in FY 1982 for both civilian and military programs or \$5.5 billion excluding the Department of Defense's space budget.

Moreover, given Japan's budgetary constraints, government support for the space program is unlikely to increase beyond the 2.5 to 4.5 percent rate of recent years. NTT, the Japan Broadcasting Corp. (NHK) and some other government-affiliated satellite users have started to underwrite part of the

cost of Japan's space program, but their combined contribution -- an estimated ¥19 billion (\$82.6 million) in the current fiscal year -- bridges only a tiny portion of the space spending gap between Japan and the United States. Even adding space-related research and development expenditures by the private sector is no help since this funding is extremely limited, totaling just ¥6.2 billion (\$27 million) in 1981.

Japan's small budget for space activities has drawn increasing criticism from its business community. Industry representatives argue that, at present and projected near-term funding levels, the government will not have available the large-capacity communications satellites that financial institutions, manufacturers and distributors will need in the late 1980s for high-speed domestic data transmission or the vehicles to launch big communications payloads by that time. With the odds stacked against a major acceleration in the nation's space program, they too have started to lobby the government to allow NTT to buy American-made satellites and foreign launch services.

This report will review the current status of Japan's satellite program and the direction in which it is moving, particularly in the area of communications satellites. It will also outline what these efforts imply for competition in the international satellite market. The changes the Japanese government has proposed in its space policy will be presented in the last section, along with an indication of whether these suggested modifications can placate domestic critics and, more importantly, avert a collision between Washington and Tokyo over satellite procurement.

Playing Catch-up

Responsibility for space development work in Japan is divided between two primary organizations. The Ministry of Education's Institute of Space and Astronautical Science (ISAS) is in charge of activities in the scientific field, including the development of scientific satellites and the vehicles to launch them. Its spacecraft are built by NEC Corp. and sent into orbit aboard launch vehicles manufactured by Nissan Motor Co., Ltd. from the ISAS Kagoshima Space Center on the southern tip of Kyushu.

R&D work on communications, broadcast and other applications satellites is performed by the National Space Development Agency (NASDA). This government-affiliated organization, which falls primarily under the jurisdiction of the Science and Technology Agency -- not, as commonly assumed, the Ministry of International Trade and Industry, also develops launch vehicles for applications satellites and conducts launches from its Tanegashima Space Center on the small southern island of the same name. Prime contractors for NASDA spacecraft are NEC (earth observation satellites), Mitsubishi Electric Corp. (MELCO) (communications satellites) and Toshiba Corp. (broadcast satellites). Mitsubishi Heavy Industries, Ltd. (MHI) is responsible for vehicle integration of NASDA's rockets.

Since Japan's first satellite was sent into orbit in 1970, NASDA and ISAS have launched a total of 30 spacecraft, 26 of them successfully (see Appendices 1 and 2). ISAS has successfully launched 14 scientific satellites whose payloads have evolved from relatively simple ones to sophisticated systems. In the process, the institute's three-stage, solid-propellant M rocket, now in the fourth generation, has established a track record as a

low-cost, reliable vehicle for launching 300-kilogram-class scientific payloads into circular orbit. In the applications field, NASDA's 12 successfully orbited satellites (which include three launched by NASA from Cape Canaveral) have also been marked by steady technological advancement. So, too, have its N series of three-stage launch vehicles, currently capable of lifting 350 kg class payloads into hard-to-achieve geostationary orbit.

This technological headway in scientific and applications satellites and launch vehicles has been the product of two different blueprints. From the start, ISAS went the independent technology development route. NASDA, in contrast, adopted a strategy that has proved highly efficient in a number of other Japanese industries. It involved teaming up Japanese manufacturers with U.S. aerospace companies -- notably, Hughes Aircraft Co., Ford Aerospace and Communications Corp. (FACC) and General Electric Co. in satellites and McDonnell Douglas Corp., Rockwell International Corp., Thiokol Corp., TRW Inc. and Aerojet TechSystems Co. in launch vehicles -- to acquire technologies that would be too expensive and time consuming for Japan to develop on its own, while at the same time funding R&D work in areas where domestic firms have an edge, like electronics.

Although cost and time considerations left Japan little choice but to follow this type of plan in applications satellites and launch vehicles, the parallel development strategy has had a number of drawbacks. For one, continued dependence on American technologies in critical satellite and launch vehicle areas, either through technical assistance, imports of "black boxes" or licensed production, has limited the freedom of Japanese companies to compete in the international space market. Perhaps more importantly, a push to replace imported expertise with domestically developed technology has left satellite users with equipment that is often not state of the art. A look at Japan's communications satellite program makes this clear.

Communications Satellites - Japan's first two communications satellites intended for operational service were launched in 1983. The CS-2 spacecraft, identical in design, were built by the Mitsubishi Electric-Ford Aerospace team, the same companies responsible for the experimental CS satellite, launched for NASDA by NASA in 1977. The CS-2 and CS share a common basic design, which was prepared by Ford Aerospace for Mitsubishi Electric. This design, however, was partially modified by the partners, working in conjunction with NTT, the CS-2's main user, to reflect some of the advances in satellite technology since the CS was planned and to incorporate special features sought by the telecommunications monopoly, which covered 60 percent of program costs.

Even with these changes, the CS-2 is less sophisticated in terms of capacity and variety of services than the communications satellites currently in operation in the United States and Europe, although it is the world's first satellite to use the high-capacity 30/20 GHz frequency band. For example, Europe's recently operational ECS-1 communications satellite can relay 12,000 telephone circuits and two television channels and can provide telephone, telex, television and specialized business services. The CS-2 satellite, in contrast, has a switching capacity of just 4,000 telephone circuits. Moreover, it is currently used only for voice transmission, although it has color television and data transmission capabilities. Still, Mitsubishi Electric and its Japanese subcontractors gained some much-needed design experience working

on the CS-2, as did NTT, which was in charge of the communications antennas and transponders (a satellite's receive-transmit links).

The CS-2 project also allowed Japanese companies to acquire the skills to manufacture key subsystems for the communications payload, since MELCO built the satellite's communications antennas and NEC made its transponders. Even more valuable was the expertise Mitsubishi Electric acquired in systems integration work. Ford Aerospace assembled the first CS-2 spacecraft at its Palo Alto, California facilities. In addition, it did the integration work on this satellite, verifying all the system's interfaces, particularly electrical connections. The American company also performed the environmental tests, which establish that the satellite should survive and work under the harsh conditions to which it is likely to be exposed during launch and on station. On the second CS-2 satellite, however, MELCO performed these three critical jobs with FACC's assistance. This transfer of responsibility helped to raise the Japanese content of the two satellites to 62 percent.

Built at a cost of Y25 billion (\$108.7 million), the two CS-2 spacecraft are designed to provide public communications services with remote Japanese islands and to maintain communications during national disasters and other emergencies. Since these operations will leave many circuits idle under normal conditions, Japan's business community has lobbied the Ministry of Posts and Telecommunications (MPT) to allow NTT to use part of the otherwise idle capacity to offer domestic commercial satellite services.

This campaign has been unsuccessful -- at least up to now. Six of the eight communications channels on the first satellite have been reserved for public communications. One of the remaining channels has been turned over to the National Police Agency, while the other has been jointly assigned to the Ministry of Construction, MPT, the Fire Defense Agency, the Japanese National Railways and Japan's electric utilities. No decision has been made about how the second CS-2 spacecraft, now an in-orbit spare, will be used, so it is still possible that NTT will be permitted to start domestic commercial satellite communications services.

If NTT does not get the go-ahead this time, potential business customers will have to wait at least until 1988 for the arrival of nationwide satellite services. That is when Japan's next generation of communications satellites is now scheduled to be launched. As presently envisioned, though, the two CS-3 satellites, even if dedicated to commercial use, will be inadequate to meet projected demand since each will provide a relay capacity of only 6,000 circuits.

What this project does offer is the opportunity for prime contractor Mitsubishi Electric and its Japanese subcontractors to develop additional satellite design and manufacturing skills -- again with the help of Ford Aerospace and NTT, which is underwriting 70 percent of the program's anticipated Y33 billion (\$143.5 million) cost. How much progress the Japanese participants are expected to make is indicated by the 80 percent domestic-content target for the CS-3 spacecraft.

The design and manufacturing technologies Japanese companies master on the CS-3 program could be further refined if two communications satellite

projects now in the planning stage at NASDA materialize. The JECs experimental spacecraft, tentatively scheduled for launch in 1990, will be used to acquire the technologies needed for the generation of communications satellites after the CS-3, while through the ETS-VI satellite, currently penciled in for launch in 1992, NASDA hopes to perfect the basic technology for the bus systems for large-capacity communications and broadcast satellites. The ultimate objective of the two proposed projects, though, is for Japanese manufacturers to develop a high-capacity satellite for NTT's communications/information network based entirely on domestic design and manufacturing technologies.

Other Applications Satellites - While in its communications satellite program Japan has apparently decided to push the development of domestic technologies rather than respond to the private sector's calls for state-of-the-art equipment, a different philosophy seems to prevail in broadcast satellites. Here, at least for now, advancements in Japanese design and manufacturing capability have taken a back seat -- albeit, an important one -- to the provision of service. As a result, Japan will be the first country in the world with a nationwide direct broadcast satellite system when the first of two BS-2 spacecraft goes into operation in May. This satellite will be used by the country's public broadcasting corporation, the underwriter of 60 percent of project costs, to provide two-channel color TV service, particularly in mountainous areas and remote islands that lack access to conventional television, and in urban environments where reception is hindered by tall buildings. The spacecraft, like the CS-2 satellites, will also be used to test new forms of satellite digital communications -- in this case, high-resolution television, digital audio sound, still picture programs, teletext and facsimile.

The BS-2, like the experimental BSE launched for NASDA by NASA in 1978, is designed and built by General Electric for prime contractor Toshiba. The Japanese company is responsible for the satellite's communications antennas and some components for other communications subsystems. Still, its contribution and that of other suppliers in Japan is expected to account for only 30 percent of the Y25 billion (\$108.7 million) cost of the BS-2a satellite and its twin, the BS-2b, scheduled for launch in the summer of 1985. This balance, NASDA hopes, will tilt in favor of substantial domestic content on Japan's next two direct broadcast satellites, but with competing project proposals by Toshiba-GE and a NEC-RCA Corp. team still under consideration, space agency officials are reluctant to specify a figure for Japan's expected participation in the BS-3 program.

NASDA seems to be more optimistic about the ability of domestic contractors to develop and manufacture the next earth observation satellite largely on their own. The MOS-1, a marine observation satellite considered to be Japan's most advanced spacecraft to date, was designed by NEC, which drew on its work with Hughes on the country's two existing and one planned meteorological satellites. Moreover, Japanese companies, with some software technical support from foreign firms, are developing and making the satellite's major subsystems, including a three-axis attitude control unit and various radiometers. Most significantly, NEC is in charge of systems integration work on the spacecraft, which is slated for launch in the summer of 1986.

Partners or Competitors?

The increasing technical sophistication apparent in Japan's satellite development program is triggering some apprehension about the competitive intentions of Japanese manufacturers, particularly in the lucrative international market for communications satellites. Concern about a challenge in the systems market is premature, however. Japanese manufacturers do not now have the experience to design, develop and build the large-capacity, multiservice communications satellites that are today's norm. Moreover, they are not expected to gain this capability in the near future, primarily because the limited thrust of NASDA's current N-II launch vehicle restricts Japanese satellites to small payloads. The space agency's next-generation H-I rocket, presently scheduled for operational service in early 1988, will not eliminate this constraint. It will only be able to lift 550-kg-class payloads into geostationary orbit, still too small to meet current international requirements. The earliest Japan could have a high-thrust rocket available is 1990 -- and this is a long shot (see JEI Report No. 10B, March 9, 1984).

Although Japanese companies are currently not in a position to make and export competitive satellite systems, they will play an important role in the international market as subcontractors on multinational satellite projects and as exporters of auxiliary equipment like earth stations and dish antennas for direct TV broadcasting. In fact, Mitsubishi Electric and NEC already have lengthy track records as suppliers of subsystems and components for the international communications satellites owned and operated by the 109-member International Telecommunications Satellite Organization (Intelsat).

MELCO is a major subcontractor for Intelsat's current-generation V and V-A spacecraft, supplying prime contractor Ford Aerospace with the two earth-coverage communications antennas, the power control electronics and the telemetry and command digital units. For its part, NEC was a key subcontractor to Hughes for Intelsat's 12 earlier IV and IV-A satellites. It will repeat this role on the upcoming Intelsat VI series, designing and manufacturing several major components of the communications payload for prime contractor Hughes. NEC, in addition, is said to be the world's largest manufacturer of Intelsat earth stations.

Washington and Tokyo at Odds

The Reagan administration's call for international competition in Japanese satellite procurement comes at an awkward time for Tokyo, in part because its applications satellite program has only recently moved into the operational phase. In addition, telecommunications policies in Japan are on the verge of fundamental change. Following the recommendation of the Administrative Reform Council, the Ministry of Posts and Telecommunications is now drafting a bill to open domestic communications services, now a NTT monopoly, to the private sector (see JEI Report No. 9B, March 2, 1984).

Apparently because of these factors, the Japanese government has found it difficult to respond to Washington's request. While Foreign Minister Abe told Ambassador Brock last October that Japan plans to continue to promote the development of satellites for use by government agencies, he left open the possibility that Japanese businesses would be allowed to buy foreign spacecraft after domestic telecommunications services are deregulated.

This is certainly not the response Washington wanted. For one thing, NTT, NHK and other government satellite users would still be unable to buy American satellites. In addition, while the bill to revise Japanese telecommunications laws is expected to be submitted to the Diet this month, the government does not know when domestic communications services will be opened to the private sector. Finally but perhaps most importantly, Foreign Minister Abe qualified Japan's willingness to allow private ventures to buy foreign satellites by adding they could do so as the need arose. This is a major qualification because the government is said to believe that business has no need for imported spacecraft, at least for now.

In subsequent bilateral discussions of this issue, Tokyo has come back time and again to the fact that American aerospace companies, far from being shut out of the Japanese satellite market, have been major players in the country's satellite development program. Government representatives have also reiterated that Japan must have a strong, independent foundation in space technologies if it is to collaborate with the United States and other countries on space-related research, such as the \$8 billion manned space station for which the Reagan administration is seeking participation by Japan and other foreign partners. The only way Japan can gain the technical expertise to contribute to projects like this, it is stressed, is through a national space development program.

For further information, contact Susan MacKnight.

The views expressed in this report are those of the author and do not necessarily represent those of the Japan Economic Institute.

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Appendix 1: Japan's Applications Satellites

<u>Name</u>	<u>Mission Objectives</u>	<u>Weight</u>	<u>Orbit</u>	<u>Launch Date</u>	<u>Launch Vehicle</u>	<u>Remarks</u>
<u>Communications/Broadcast Satellites</u>						
Medium-Capacity Communications Satellite for Experimental Purposes (CS/Sakura)	Experiments with satellite communications systems using quasi-millimeter waves and developing techniques for operating satellite communications systems.	350 kg	Geostationary	December 1977	Thor-Delta (NASA)	Mission completed, but still operating.
Experimental Communications Satellite (ECS/Ayame)	Development of technologies for launching, tracking and controlling communications satellites, as well as experiments with millimeter waves.	130 kg	Geostationary	February 1979	N-I-5	Failed to achieve planned orbit.
Experimental Communications Satellite-2 (ECS-b/Ayame-2)	Same as ECS/Ayame.	130 kg	Geostationary	February 1980	N-I-6	Failed to achieve planned orbit.
Communications Satellite-2a (CS-2a/Sakura-2a)	Provide public communications services for remote islands and maintain communications during national disasters and other emergencies, as well as develop satellite communications technology.	350 kg	Geostationary	February 1983	N-II-3	In operation.
Communications Satellite-2b (CS-2b/Sakura-2b)	Same as CS-2a/Sakura-2a.	350 kg	Geostationary	August 1983	N-II-4	In operation.
*Communications Satellite-3a (CS-3a)	Expand communications services provided by CS-2 and advance technology for communications satellites.	550 kg	Geostationary	Early 1988	H-I-1	Design work started FY 1982; manufacturing and test phase to start FY 1985.
*Communications Satellite-3b (CS-3b)	Same as CS-3a.	550 kg	Geostationary	Summer 1988	H-I-2	Design work started FY 1982; manufacturing and test phase to start FY 1985.
Medium-Scale Broadcasting Satellite for Experimental Purposes (BSE/Yuri)	Image and audio transmission tests by satellite and development of techniques for operating satellite broadcasting systems.	350 kg	Geostationary	April 1978	Thor-Delta (NASA)	Mission completed.
Broadcasting Satellite-2a (BS-2a)	Eliminate poor television reception in mountainous areas, outlying islands and urban environments with tall buildings and develop satellite broadcast technology.	350 kg	Geostationary	January 1984	N-II-5	In geostationary orbit; will go into operation in May.
*Broadcasting Satellite-2b (BS-2b)	Same as BS-2a.	350 kg	Geostationary	Summer 1985	N-II-7	In final manufacturing and testing stage.

<u>Name</u>	<u>Mission Objectives</u>	<u>Weight</u>	<u>Orbit</u>	<u>Launch Date</u>	<u>Launch Vehicle</u>	<u>Remarks</u>
*Broadcasting Satellite-3a (BS-3a)	Expand broadcasting services provided by BS-2 and home satellite broadcasting technology.	550 kg	Geostationary	Early 1989 (planned)	H-1	Design phase started FY 1983; manufacturing and testing to start 1986.
*Broadcasting Satellite-3b (BS-3b)	Same as BS-3a.	550 kg	Geostationary	Summer 1990 (planned)	H-1	Design phase started FY 1983; manufacturing and testing to start 1986.
<u>Earth Observation/Meteorological Satellites</u>						
Ionosphere Sounding Satellite (ISS/Ume)	Observe worldwide distribution of critical frequencies in ionosphere to improve short-wave communications.	141 kg	Circular	February 1976	N-I-2	Lost contact one month after launch.
Ionosphere Sounding Satellite-2 (ISS-b/Ume-2)	Same as ISS/Ume.	141 kg	Circular	February 1978	N-I-4	Mission completed February 1983.
Geostationary Meteorological Satellite (GMS/Himawari)	Participate in the Global Atmosphere Research Program (GARP), with object of improving the accuracy of Japanese weather forecasting through the observation of cloud formations.	303 kg	Geostationary	July 1977	Thor-Delta (NASA)	In-orbit spare for GMS-2 since January 1982.
Geostationary Meteorological Satellite-2 (GMS-2/Himawari-2)	Improvement of meteorological service in Japan and development of meteorological satellite technology.	296 kg	Geostationary	August 1981	N-II-2	Became inoperative January 1984; GMS took over its functions same month.
*Geostationary Meteorological Satellite-3 (GMS-3)	Continued improvement of meteorological service in Japan and further development of meteorological satellite technology.	296 kg	Geostationary	Summer 1984	N-II-6	In final test stage.
*Marine Observation Satellite-1 (MOS-1)	Observe marine phenomena, especially the colors and surface temperature of the sea, and establish the technologies common to earth observation satellites.	750 kg	Sun synchronous	Summer 1986	N-II-8	Development work started FY 1983.
*Earth Resources Satellite-1 (ERS-1)	Establish active observation technologies and collect information on land use, agriculture, forestry and the environment in addition to coastal zone monitoring.	1400 kg	Sun synchronous	1990 (planned)	H-1	In research phase; design work to start FY 1984.
*Experimental Geodetic Payload (EGP)	Improve accuracy of geodetic surveys using the conventional triangular network.	675 kg	Circular	Early 1986	H-1 (two-stage test flight)	Manufacturing and test stage began FY 1983.

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<u>Name</u>	<u>Mission Objectives</u>	<u>Weight</u>	<u>Orbit</u>	<u>Launch Date</u>	<u>Launch Vehicle</u>	<u>Remarks</u>
<u>Engineering Test Satellites</u>						
Engineering Test Satellite-I (ETS-I/Kiku)	Confirm launch technology, acquire satellite tracking and control technology, test antenna performance and examine the satellite environment.	82 kg	Circular	September 1975	N-I-1	Mission completed.
Engineering Test Satellite-II (ETS-II/Kiku-2)	Learn technologies to put satellites in geostationary orbit, acquire geostationary satellite tracking/control and attitude-control technologies and carry out functional tests of onboard equipment.	130 kg	Geostationary	February 1977	N-I-3	Mission completed, but still operating.
Engineering Test Satellite-III (ETS-III/Kiku-4)	Develop production and operation technologies for satellites requiring high power and test three-axis attitude control, deployable solar panels and onboard equipment.	385 kg	Circular	September 1982	N-I-7	Mission completed, but still operating.
Engineering Test Satellite-IV (ETS-IV/Kiku-3)	Verify launch performance of N-II vehicle, acquire data on launch environment as well as technologies for producing and managing large satellites and test functions of onboard equipment.	640 kg	Highly elliptic	February 1981	N-II-1	Mission completed, but still operating.
*Engineering Test Satellite-V (ETS-V)	Confirm launch performance of three-stage H-I vehicle, establish basic technologies for geostationary three-axis stabilized satellite bus systems and implement mobile satellite communications experiments.	550 kg	Geostationary	Summer 1987	H-I (three-stage test flight)	Design phase began FY 1983.

*Scheduled as of August 1983.

Source: Japan, National Space Development Agency, NASDA '83-'84

Appendix 2: Japan's Scientific Satellites

<u>Name</u>	<u>Mission Objectives</u>	<u>Weight</u>	<u>Orbit</u>	<u>Launch Date</u>	<u>Launch Vehicle</u>
Test Satellite (Ohsumi)	Learn satellite launch technology and perform engineering test of satellite.	24 kg	Elliptic	February 1970	L-4S-5
Test Satellite (MS-T1/Tansei)	Test satellite environment and satellite functions after entry into orbit.	63 kg	Circular	February 1971	M-4S-2
First Scientific Satellite (MS-F2/Shinsei)	Observe ionosphere, cosmic rays and solar high-frequency radio emissions.	66 kg	Elliptic	September 1971	M-4S-3
Second Scientific Satellite (Rexs/Dempa)	Observe plasma waves, plasma density, electron flux, electromagnetic waves and geomagnetism.	75 kg	Elliptic	August 1972	M-4S-4
Test Satellite (MS-T2/Tansei-II)	Measure launch vehicle performance and perform engineering test of satellite.	56 kg	Elliptic	February 1974	M-3C-1
Third Scientific Satellite (Srats/Taiyo)	Observe solar soft X-rays, solar vacuum ultraviolet radiations, geocoronal ultraviolet lines and ionosphere.	86 kg	Elliptic	February 1975	M-3C-2
Test Satellite (MS-T3/Tansei-III)	Measure launch vehicle performance and perform engineering test of satellite.	129 kg	Elliptic	February 1977	M-3H-1
Fifth Scientific Satellite (Exos-A/Kyokko)	Observe the density, temperature and composition of plasma and the distribution of electron energy, aurora and particle rays.	126 kg	Elliptic	February 1978	M-3H-2
Sixth Scientific Satellite (Exos-B/Jikiken)	Observe electron density, particle rays, plasma waves and wave-particle interaction.	90 kg	Highly elliptic	September 1978	M-3H-3
Fourth Scientific Satellite (Corsa-b/Hakuchō)	Observe X-ray stars, X-ray bursters and very soft X-ray nebulae.	96 kg	Near circular	February 1979	M-3C-4
Test Satellite (MS-T4/Tansei-IV)	Measure launch vehicle performance and perform engineering test of satellite.	185 kg	Near circular	February 1980	M-3S-1
Seventh Scientific Satellite (Astro-A/Hinotori)	Observe two-dimensional hard X-ray image of solar flares and solar particle rays.	188 kg	Near circular	February 1981	M-3S-2
Eighth Scientific Satellite (Astro-B/Tenma)	Conduct two-dimensional imaging of celestial X-ray sources like X-ray nebulae and X-ray galaxies as well as observe X-ray bursters with high temporal and spectrum resolution.	180 kg	Elliptic	February 1982	M-3S-3
Ninth Scientific Satellite (Exos-C)	Observe phenomena in the stratosphere and mesosphere through extensive use of optics as well as clarify the curious behavior of the ionosphere over the South Atlantic Geomagnetic Anomaly found by the Taiyo satellite.	210 kg	Elliptic	February 1984	M-3S-4